Quiet Green Transport Study

FY'01 Review

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Quiet Green Transport Study Overview

Quiet Green Transport Goal:

- **Substantially mitigate or eliminate noise and emission related environmental impacts of commercial aviation**
  - **Objectionable noise contained within airport boundary**
  - **No substance emitted where it has a significant environmental impact**

Study Objectives:

- **Define revolutionary aircraft concepts focused toward "Quiet Green Transport" goal**
- **Identify technology advances necessary for concept feasibility**

Quiet Green Transport Study Overview

Study Approach:

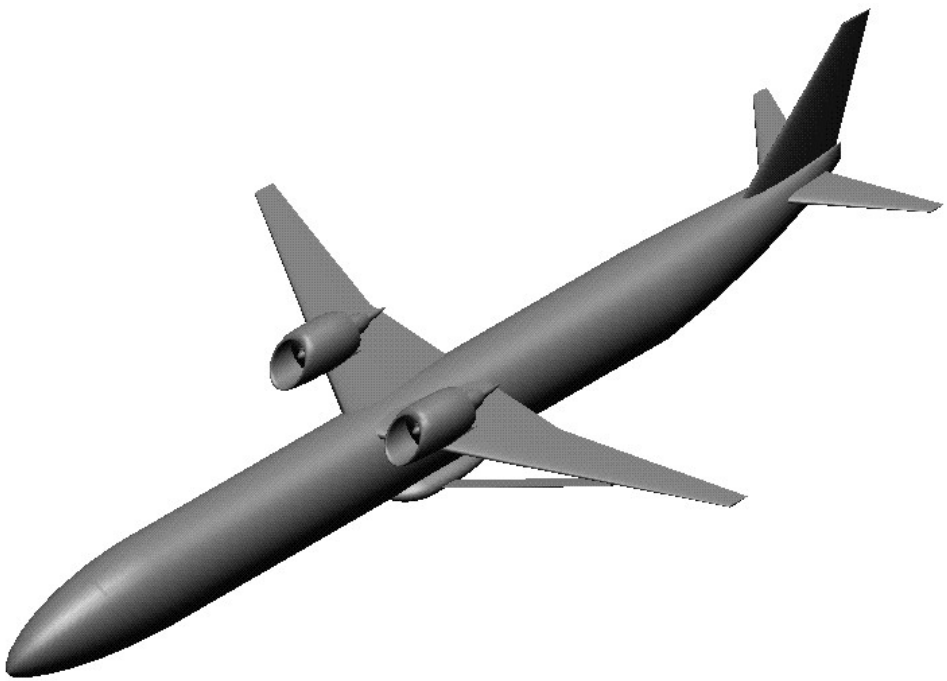
- **"Brainstorm" concept design options**
- **Downselect options and build-up aircraft concepts of varying risk/benefit**
- **For each concept defined:**
  - **Develop a baseline model**
  - **Perform sensitivity analyses to identify key technology areas**
  - **Determine technology improvements required for feasibility**
  - **Assess noise and emission benefits**

Quiet Green Transport Study Overview

Study Groundrules and Assumptions:

- Assumed scenario for RASC time horizon
  - Economic incentives for reducing aircraft noise and emissions
  - Transition to alternate fuels in many energy sectors
- Qualitative downselect of concept design options
- Concepts developed for a single commercial transport class
  - 225 passenger, 3500 nmi mission selected
- Concept "feasibility" characterized by weight relative to current technology conventional baseline
- Analysis performed at a high level, using data from other studies as appropriate
- Concept benefits assessed for single event noise, community noise, landing-takeoff cycle (LTO) emissions, and total emissions

Quiet Green Transport Concepts



Concept A

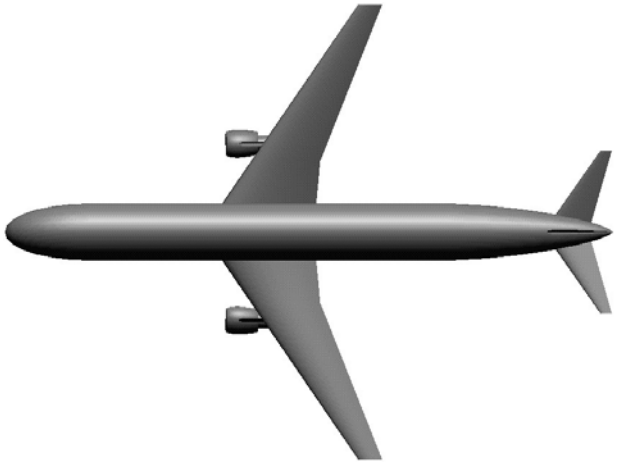
Revolutionary Elements

- Ultra-high bypass ratio H_2 turbofan engines, LH_2 fuel
- Over-wing engine placement
- Scarf Inlets
- Transonic Strut-Braced Wing airframe
- Steep approach (6°)
- "Contrail Avoidance" cruise

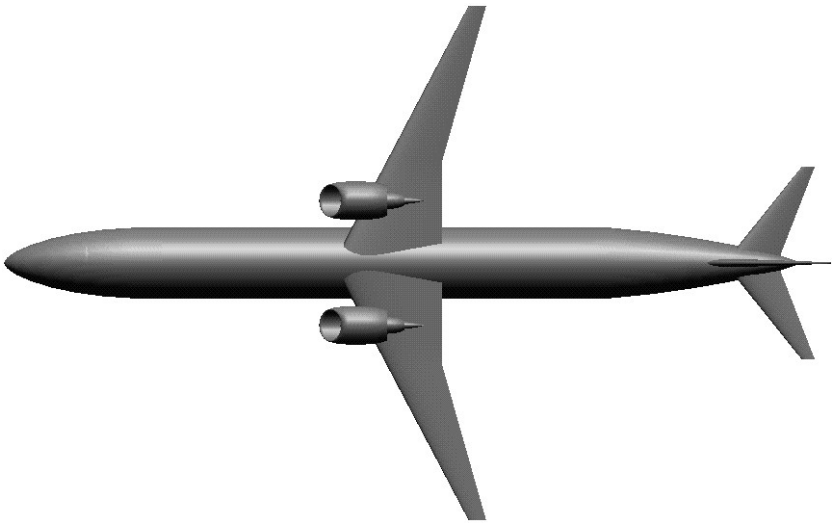
Benefits

- No aircraft emissions of CO_2, CO, hydrocarbons, SO_X, soot
- Forward and aft noise shielding
- Increased wing aero and structural efficiency
- Reduced approach noise
- Potential to eliminate contrails

Concept A Basic Characteristics



Conventional



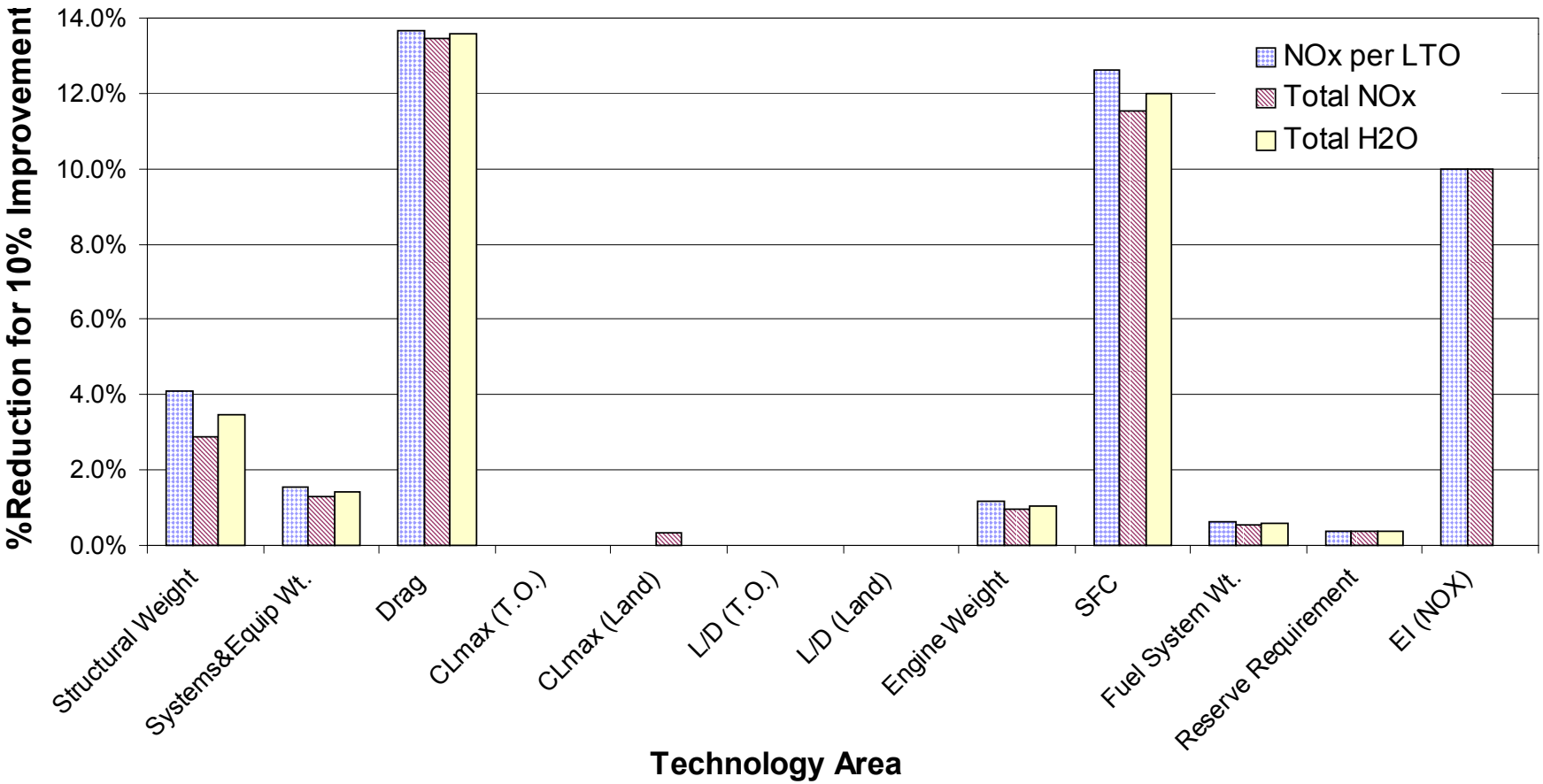
Concept A

	Conventional	Concept A
Wing Area, ft^2	2170	2350
Wing Span, ft	132	149
Fuselage Diameter, ft	16.5	20.3
Fuselage Length, ft	176	230
Thrust per engine (SLS), lb	43,400	51,600
Operating Weight Empty, lb	138,600	211,400
Fuel Weight (3500 nmi), lb	85,000	39,800
Gross Weight (3500 nmi), lb	270,600	298,300

Concept A Emission Characteristics

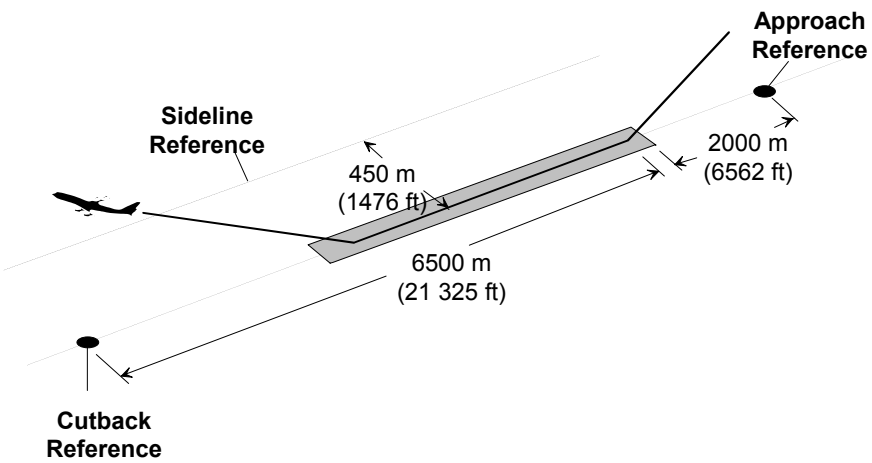
	Conventional Optimum Alt. Cruise	Concept A Optimum Alt. Cruise	Concept A "Contrail Avoid." Cruise
Total Aircraft Energy Consumption, BTU	1.37×10^9	1.49×10^9 (+9%)	1.79×10^9 (+31%)
Total Aircraft CO_2 Emissions, lb	235,400	0 (-100%)	0 (-100%)
Total Aircraft H_2O Emissions, lb	92,300	258,200 (+180%)	309,700 (+235%)
Aircraft H_2O Emissions above 25,000 ft, lb	83,900	237,100 (+183%)	0 (-100%)
Total Aircraft NO_X Emissions, lb	810	962 (+19%)	1291 (+59%)
LTO Cycle NO_X Emissions, lb	37.8	31.1 (-18%)	31.1 (-18%)

Concept A Emission Sensitivities



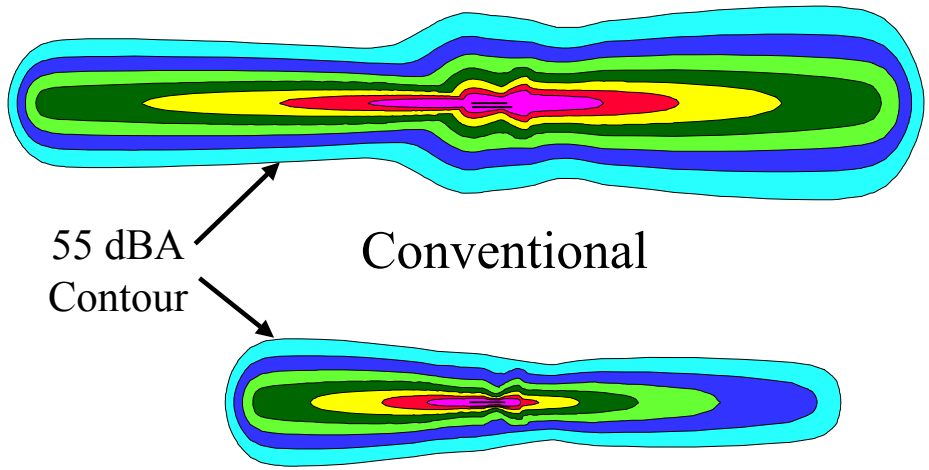
Concept A Noise Characteristics

Noise at Certification Points



	Conventional	Concept A
Sideline EPNL, dB	96.0	84.3 **(-11.7 dB)**
Cutback EPNL, dB	90.2	80.0 **(-10.2 dB)**
Approach EPNL, dB	98.5	87.4 **(-11.1 dB)**

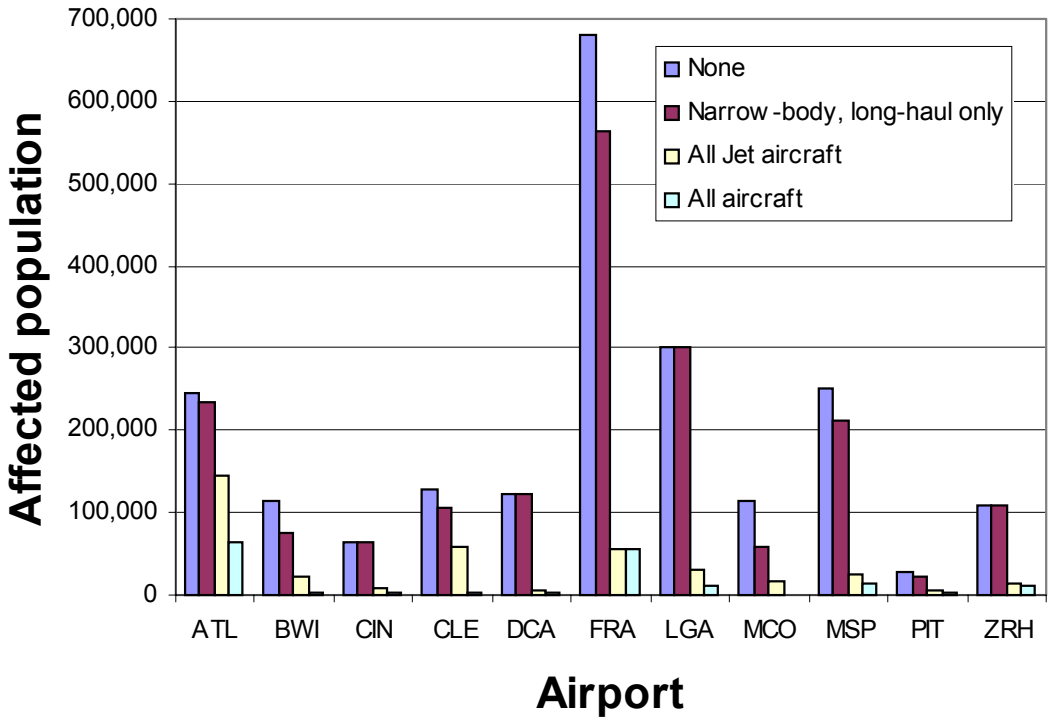
Sound Exposure Level Contours



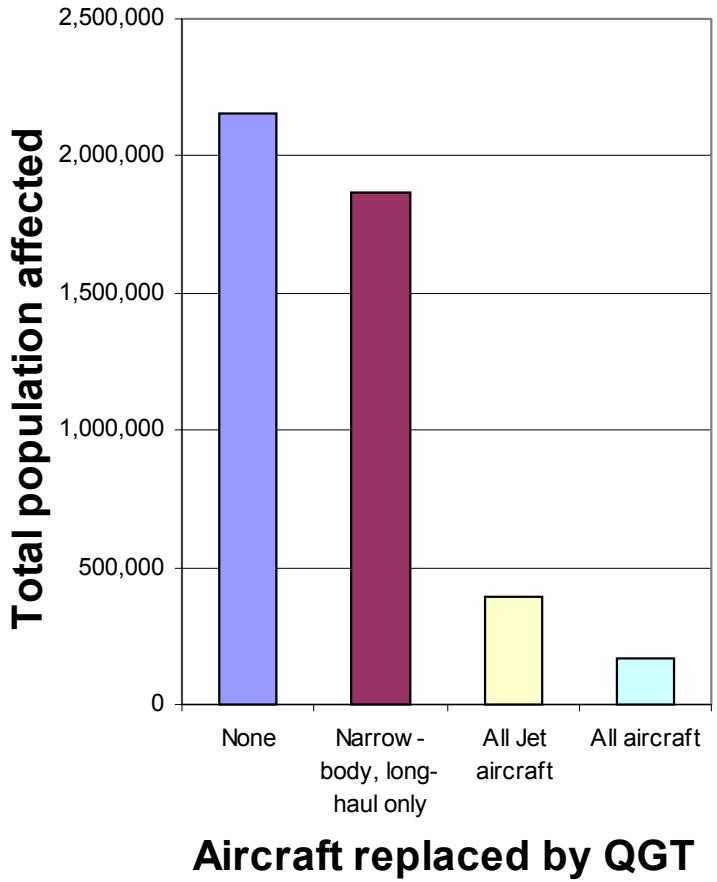
53% Reduction in 55dBA Contour Area

Concept A Community Noise Impact
Effect of 11 dBA Benefit in 2017

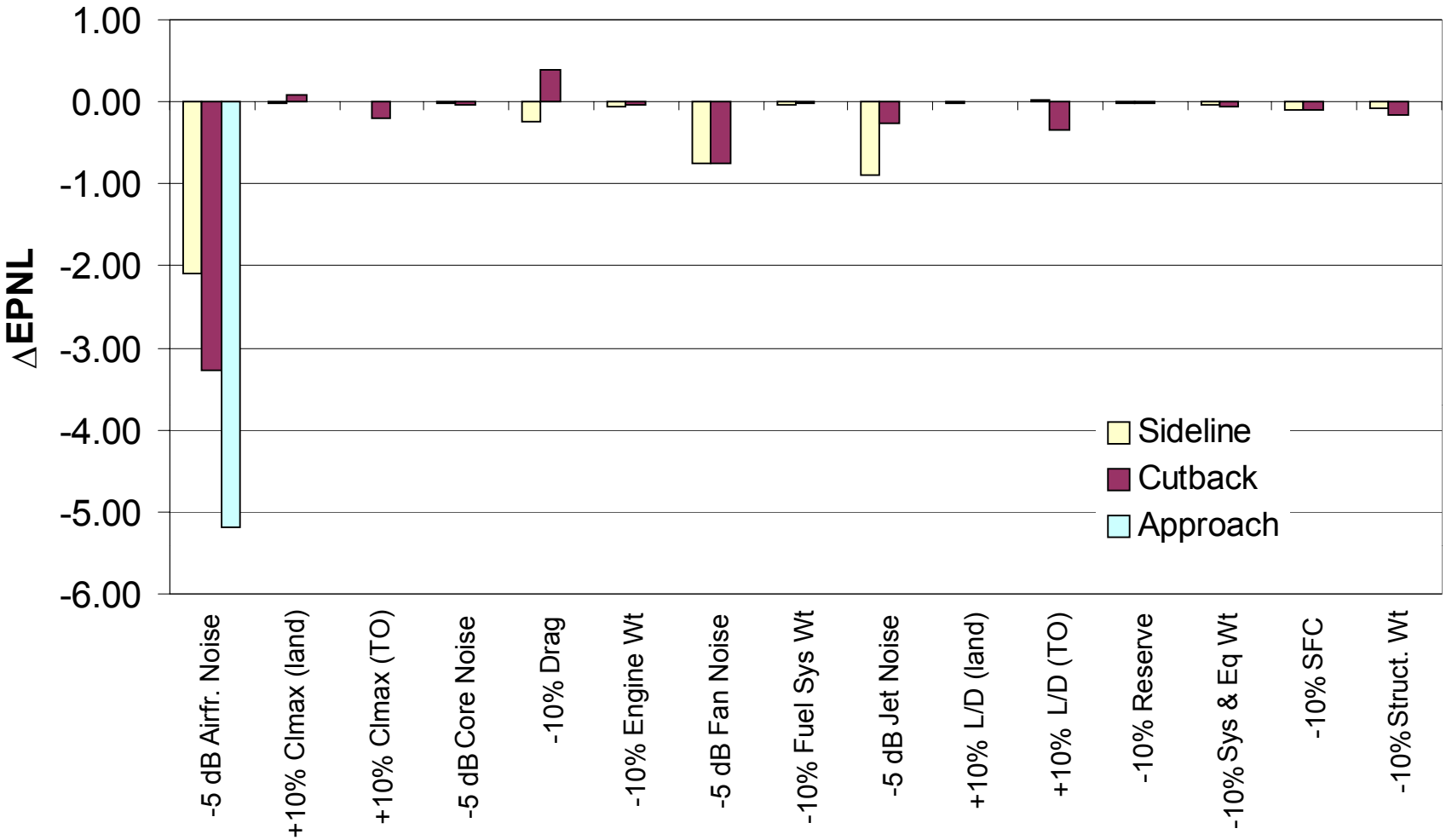
55+ dB DNL Population Impact per Airport



Total for 11 Airports



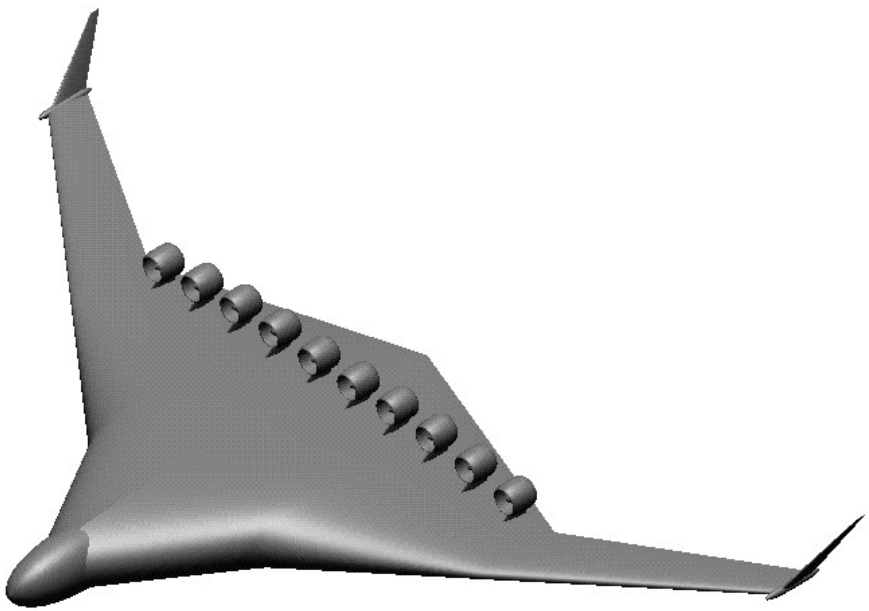
Concept A Noise Sensitivities



Concept A Technology Assessment

- **Revolutionary technologies needed to make LH_2 fuel practical and environmentally sound**
  - **Environmentally friendly and economical H_2 production**
  - **Low cost, low energy liquefaction processes**
  - **Efficient H_2 delivery and storage**
- **Near term technologies probably sufficient to solve aircraft design challenges**
  - **Long life, reliable, and maintainable LH_2 fuel system**
  - **Strut interference drag reduction and fuselage attachment mechanism**
  - **Variable area fan exhaust nozzle for ultra-high bypass ratio engine**
  - **Over-wing engine integration and scarf inlet design**
- **Noise and emission benefits greatly enhanced by technology advances in:**
  - **Airframe noise reduction**
  - **Low NO_X combustion**
  - **Drag reduction**
  - **Engine fuel efficiency**
  - **Structural weight**

Quiet Green Transport Concepts



Concept B (Notional)

- Evaluation continuing

Revolutionary Elements

- H_2 fuel cell propulsion, LH_2 fuel
- Distributed propulsion
- Blended Wing Body (BWB) airframe
- Retractable aft noise shield
- Seamless high-lift system
- Steep approach (12°)
- "Contrail Avoidance" cruise

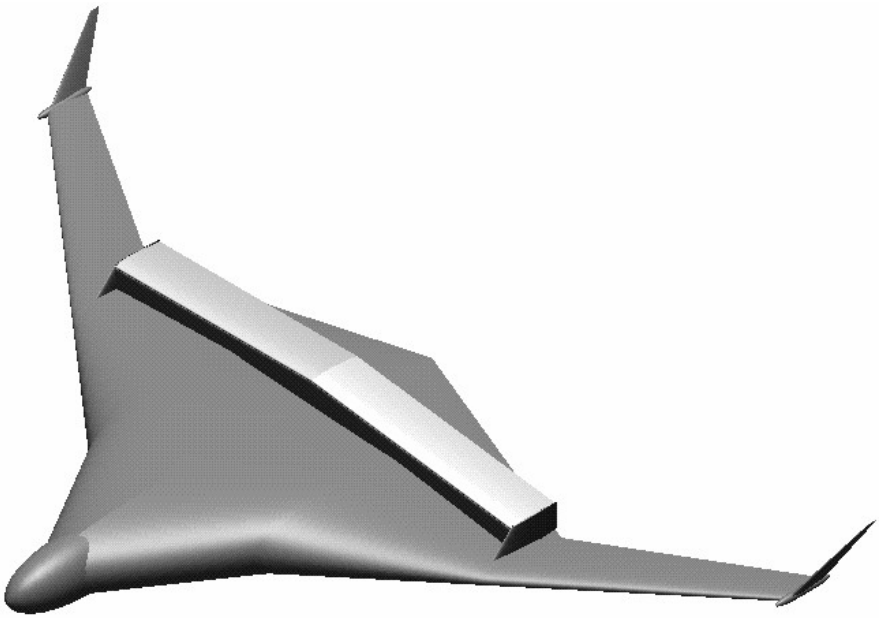
Benefits

- Only H_2O emitted by aircraft
- Reduced total "engine" source noise
- Increased aerodynamic efficiency
- Forward and aft "engine" noise shielding
- Reduced flap noise
- Reduced approach noise
- Potential to eliminate contrails

Concept B Evaluation Status

- **New analysis capabilities needed to perform evaluation**
  - **Suitable size BWB model**
  - **Fuel cell based propulsion system model**
- **Development of appropriate size BWB model initiated**
  - **Previous BWB models for 800 passenger class**
  - **Smaller BWB model being developed using available data**
  - **Pursuing additional 450 passenger BWB data from Boeing**
- **Initial model of fuel cell based propulsion system completed**
  - **Developed at GRC by Propulsion Systems Analysis Office with assistance from Electrochemistry Branch**
  - **Incorporated into the Numerical Propulsion System Simulation code**
  - **Additional elements and complexity being added to improve fidelity**
  - **Model will provide much needed capability for fuel cell aircraft studies**

Quiet Green Transport Concepts



Concept C (Notional)

- Modeling has not yet begun

Revolutionary Elements

- Emissionless electric propulsion
- Distributed propulsion
- Variable geometry BWB airframe
- Retractable aft noise shield
- Seamless high-lift system
- Steep approach (12°)
- Assisted T.O. and power-off landing

Benefits

- Eliminate all in-flight emissions
- Reduced total “engine” source noise
- Increased aerodynamic efficiency
- Forward and aft “engine” noise shielding
- Reduced flap noise
- Reduced approach noise
- Reduced T.O. thrust

Quiet Green Transport Summary

- Analysis conducted at a high level, only a single vehicle class studied
- Study focused on aircraft concepts and their technology requirements, ultimate viability of concepts depends largely on issues outside the scope of this study
- Concept A Results
  - Significant noise and emissions benefits, atmospheric science investigation necessary to assess effectiveness of H_2O impact mitigation strategy
  - "Quiet Green Transport" goal not fully achieved
  - Technology Assessment:
    - aircraft design challenges can probably be met with current to near term technologies
    - revolutionary advances in LH_2 fuel production, transportation, and storage technology are required for concept to be practical
    - advances in airframe noise, low NO_X combustion, drag reduction, engine fuel efficiency, and structural weight would enhance environmental benefits
- Quiet Green Transport Study was selected for continuation in FY'02